BROOKHAVEN
NATIONAL LABORATORY

HISTORY, EVOLUTION AND DESIGN OF THIN SEPTUM MAGNETS AT BNL

Michael Mapes

The 14th ICFA mini-workshop on septa devices

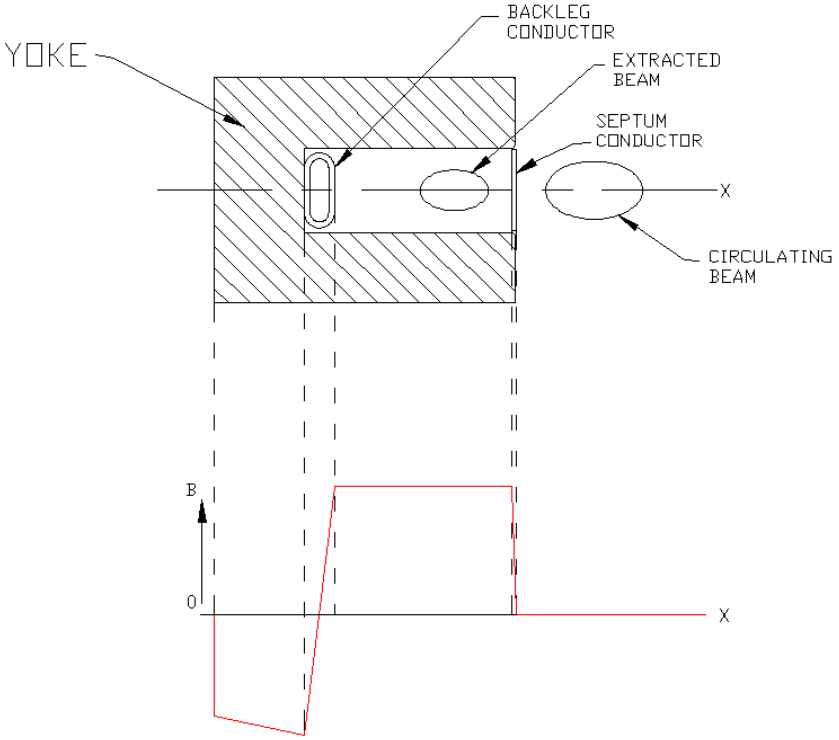
OUTLINE

- THIN SEPTUM DESIGN
- F5 - OLD DESIGN WITH SOME UPGRADES
- POWER/COOLING FEERTHRU DESIGN
- COOLING TUBE BRAZING
- PORCELAIN COATING FOR ELECRICAL INSULATION
- D3 LATEST DESIGN
- FUTURE & EXISTING SEPTUM DATA
- CONCLUSION

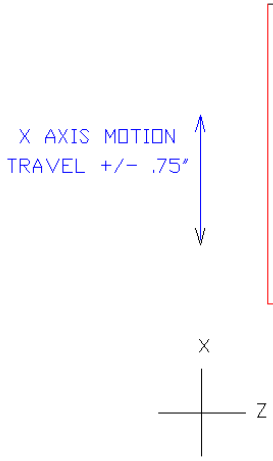
BROOKHAVEN NATIONAL LABORATORY

THIN SEPTUM DESIGN

SEPTUM CROSS SECTION



MAGNETIC FIELD B VERSUS X-AXIS



SEPTUM MAGNET MOUNTED INSIDE VACUUM CHAMBER

VACUUM CHAMBER MOUNTED ON MOTION SYSTEM

POSITIONS SEPTUM IN RELATION TO BEAM

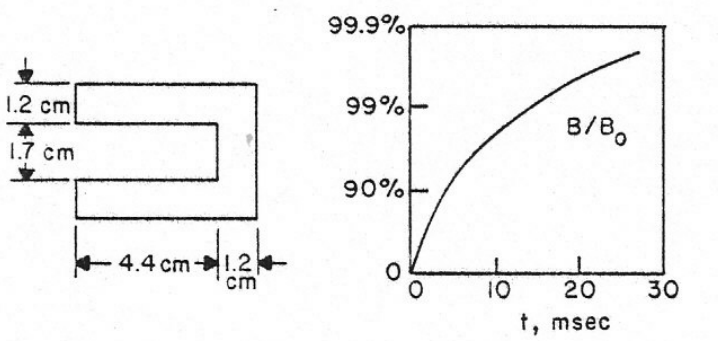
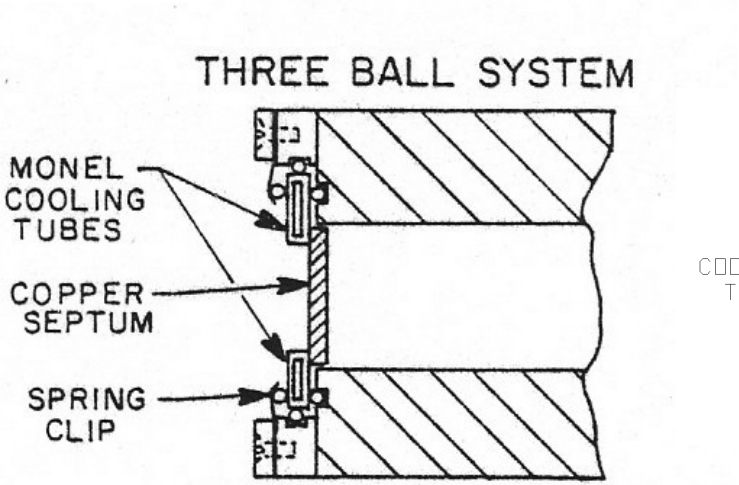
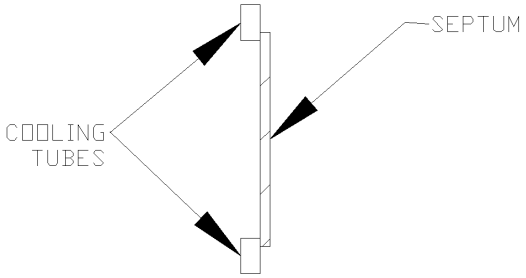


Fig. 1. Magnet core cross section (dimensions in cm), and measured risetime.

BROOKHAVEN NATIONAL LABORATORY

THIN SEPTUM DESIGNS

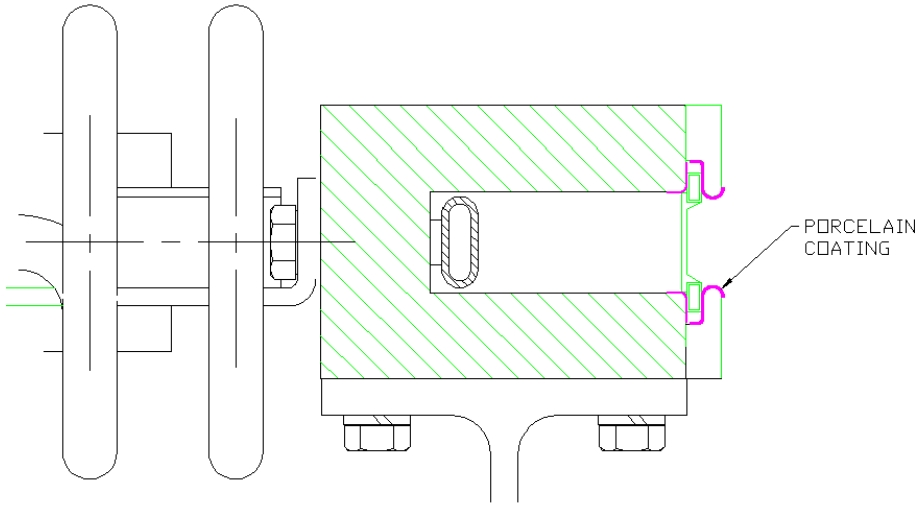


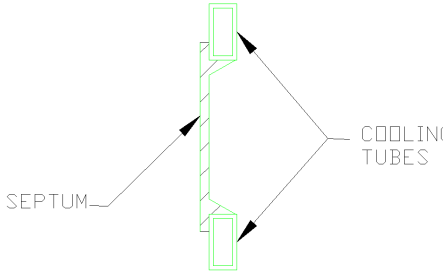


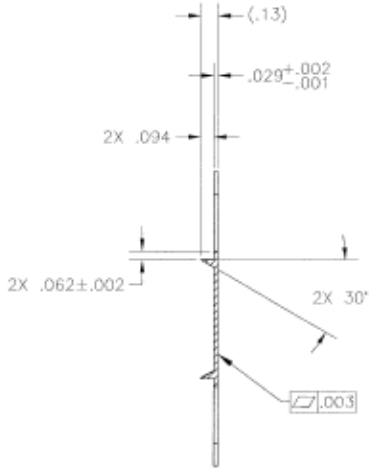
MATERIALS MUST BE RADIATION HARD

OTHER INSULATING MATERIALS USED

- VESPEL
- ALUMINUM OXIDE



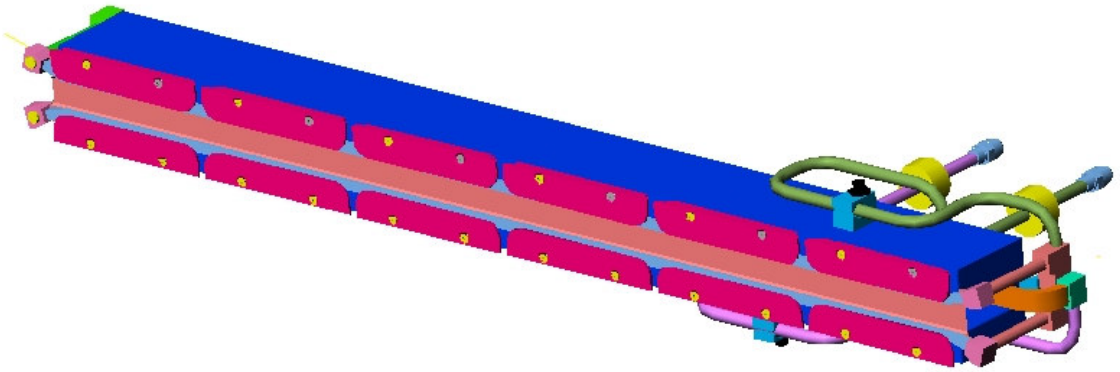




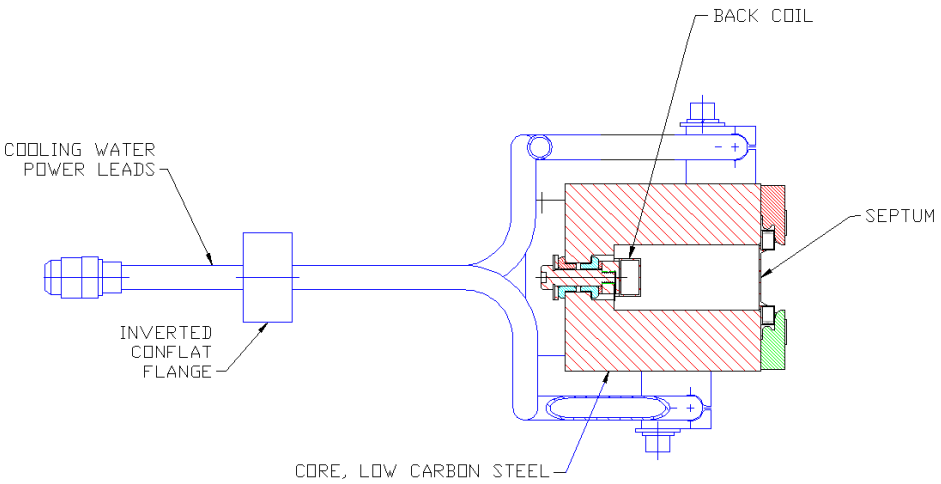
SECTION A–A

BROOKHAVEN NATIONAL LABORATORY

THIN SEPTUM DESIGN



Septum Magnet Assembly

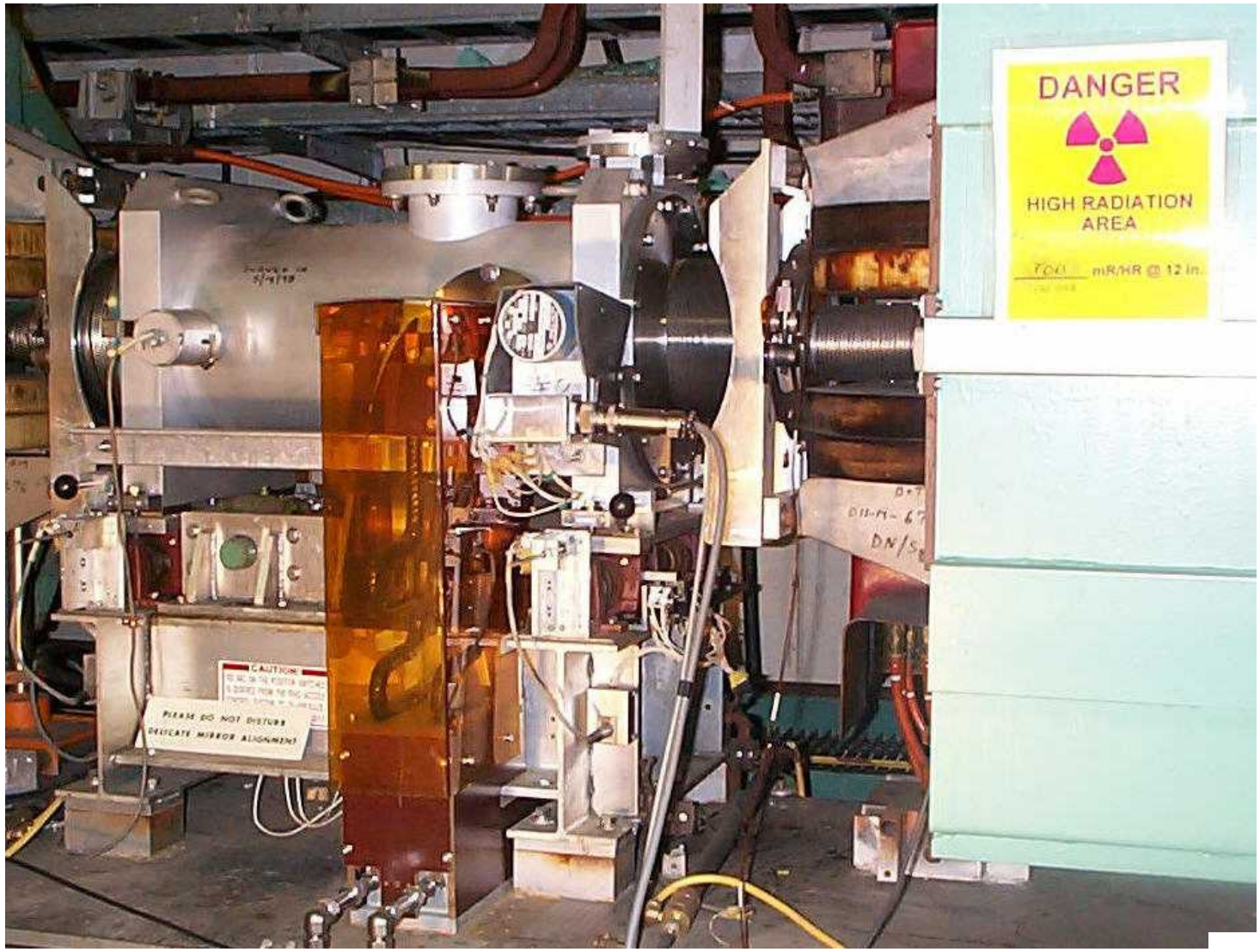


Magnet Assembly End View

VERY HIGH CURRENT DENSITIES 90-140 A/mm^2

- ALL POWER LEADS WATER COOLED
- TEMPERATURE MUST BE MONITORED
- MAGNET MOUNT INSIDE THE VACUUM CHAMBER

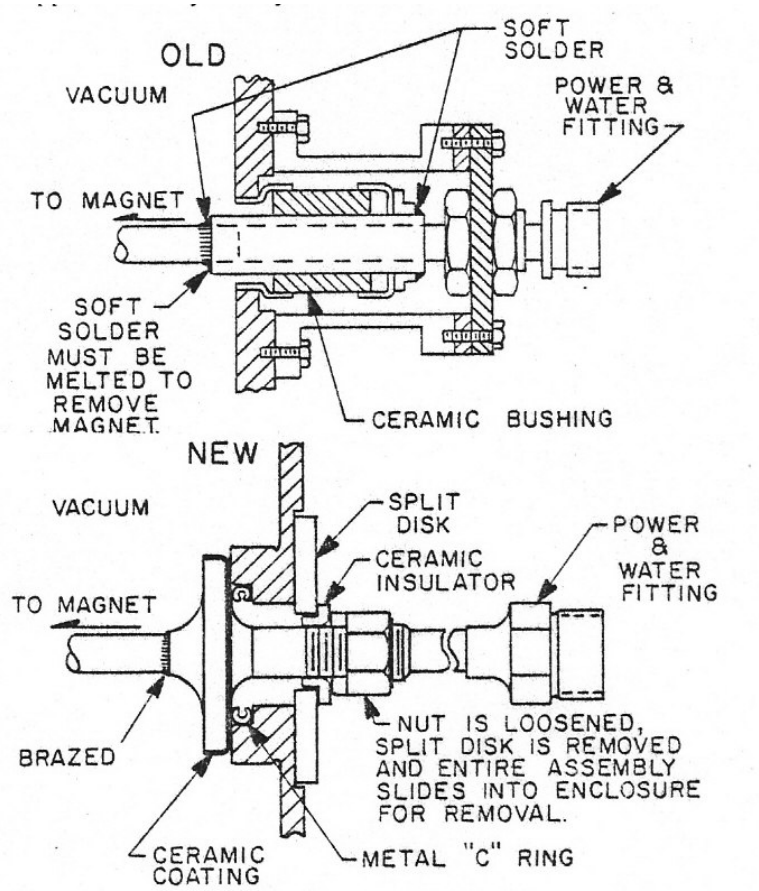
F5 INSTALLATION IN AGS RING

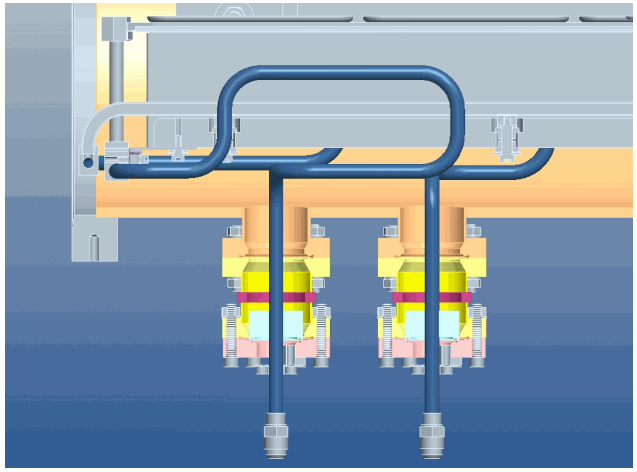


BROOKHAVEN NATIONAL LABORATORY

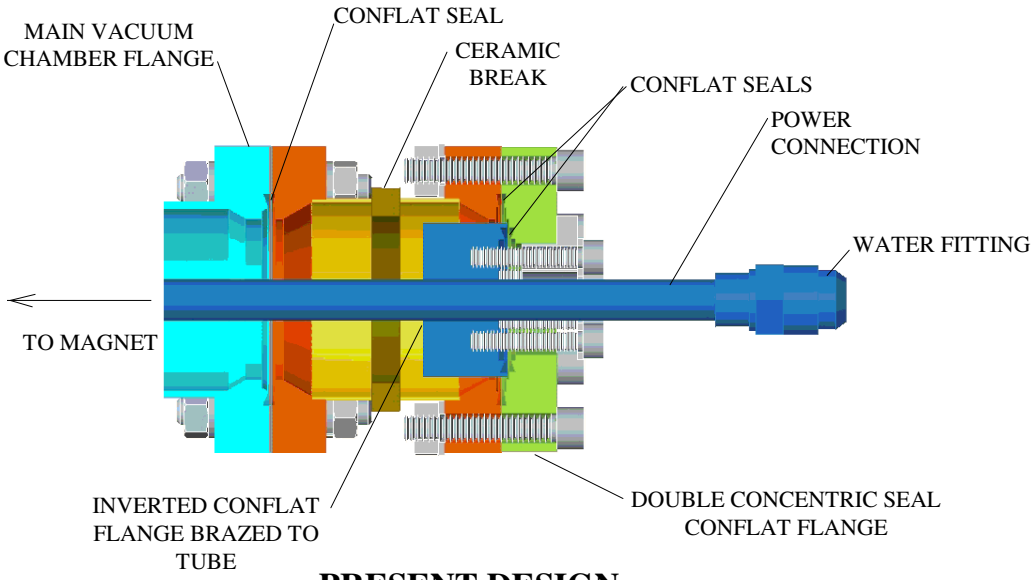
BROOKHAVEN NATIONAL LABORATORY

POWER/COOLING FEEDTHROUGH DESIGN





PLAN SECTION VIEW OF COOLING/POWER FEEDTHROUGH



PRESENT DESIGN

2D MAGNETIC CALCULATIONS

D3 THIN SEPTUM

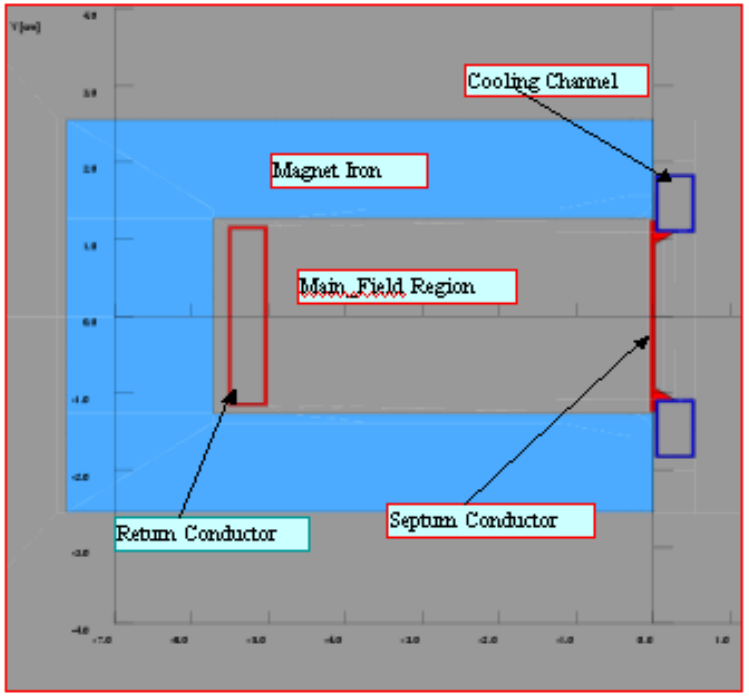
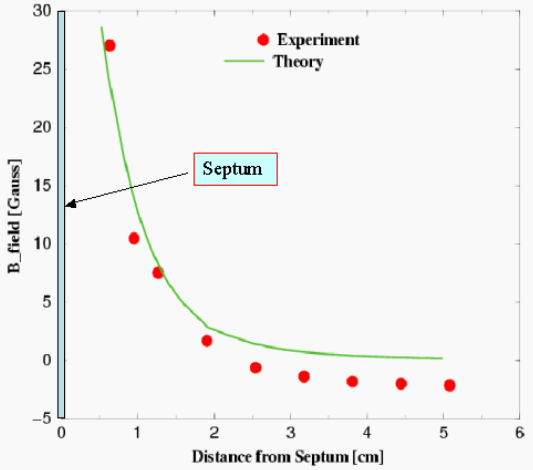


Figure 1. Cross section of the Septum magnet showing the "Magnet Iron" the "Return" and "Septum" Conductors, the "Cooling Channel". The "Main_Field_Region" corresponds to the extracted beam, and the "Fringe" region to the circulating beam.

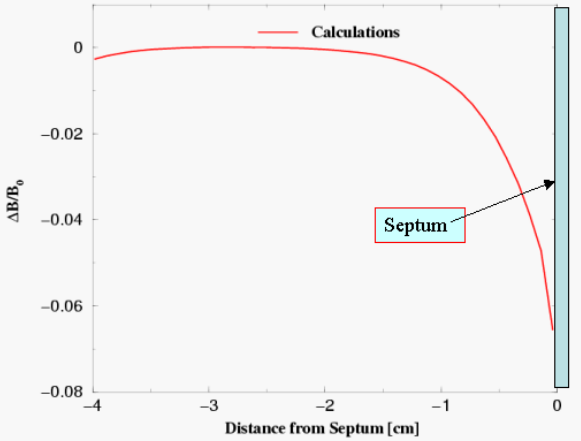
CURRENT DENSITIY

MONEL TUBES $J=1.888\times10^{6}$ A/m^2

COPPER SEPTUM $J=5.871\times10^{7}$ A/m^2



Experimental and Calculated values of magnetic field in the "Fringe" field region, plotted as a function of distance from the edge of the septum.



Field Homogeneity in the "Main_Field_Region" of the magnet

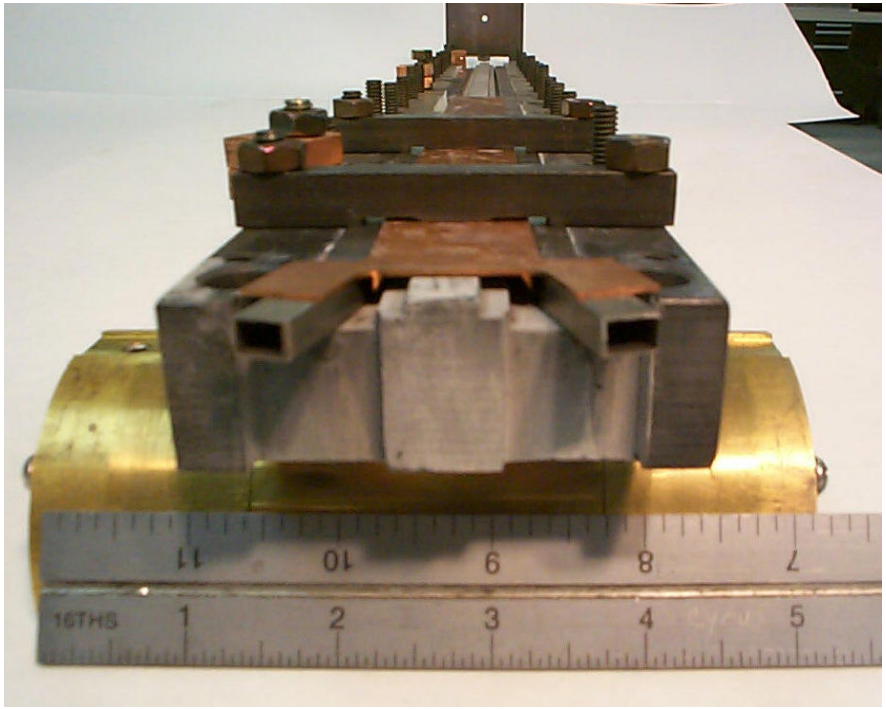
Plot of the magnetic field homogeneity in the "Main_Field_Region" from the edge of the "septum" to a distance 4 cm inside the magnet. The maximum magnetic field in the "main_Field_Region" is 462.5 Gauss.

BROOKHAVEN NATIONAL LABORATORY

SEPTUM BRAZING

Braze Material History

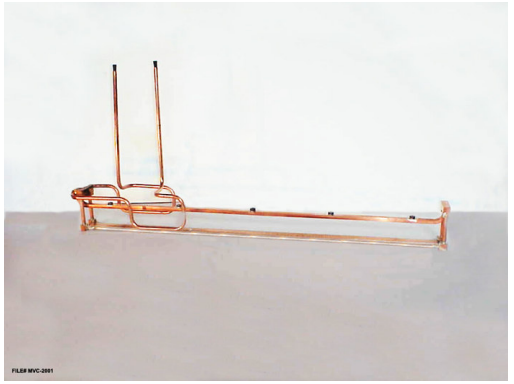
- Easy Flow 45 – Hand Torch
- Braze 707 ribbon in vacuum furnace
- B Ag 8 – H_2 furnace
- B Ag 8 – Vacuum Furnace with Ar



SEPTUM MOUNTED IN BRAZING FIXTURE

Keys to Making Septum Braze Joints

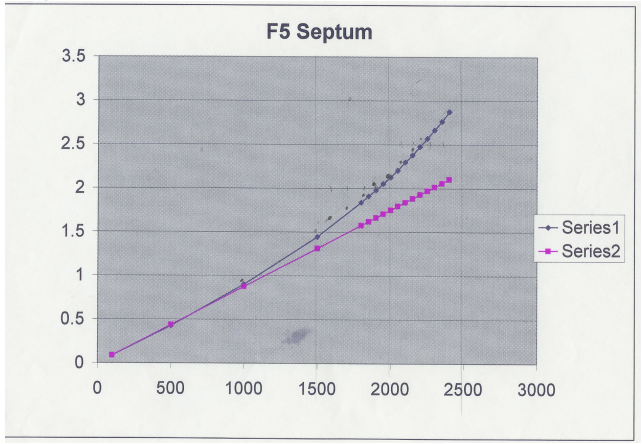
- Clean Parts- Citric Acid- copper
  Detergent –Monel
  D.I. Water rinse all parts
- Good Fixturing – Proper Clearances
- Vacuum Braze
  Manuf. WESGO -Material Cusil
  Spec# B Ag 8 –100 mesh
  800 mtorr Ar
  Ramp 1450°F – hold 5 min
  Nicrobraze stop-off



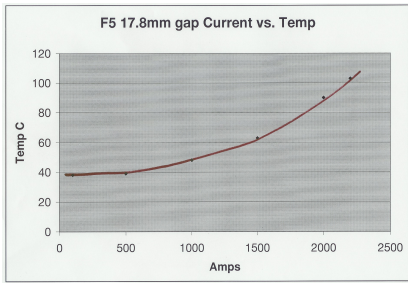
ASSEMBLED COIL

BROOKHAVEN NATIONAL LABORATORY

F5 LOAD TESTING

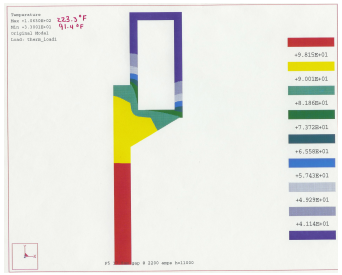


SEPTUM VOLTAGE DROP VS CURRENT



SEPTUM TEMPRATURE VS DC CURRENT

1.8 GPM WATER FLOW

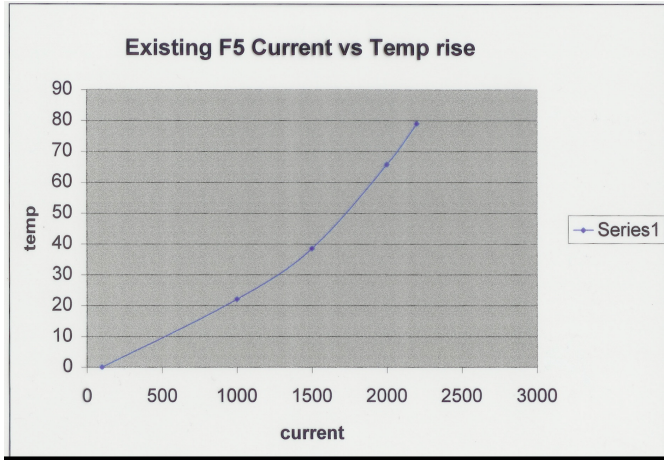


FEA ANALYSIS STEADY STATE

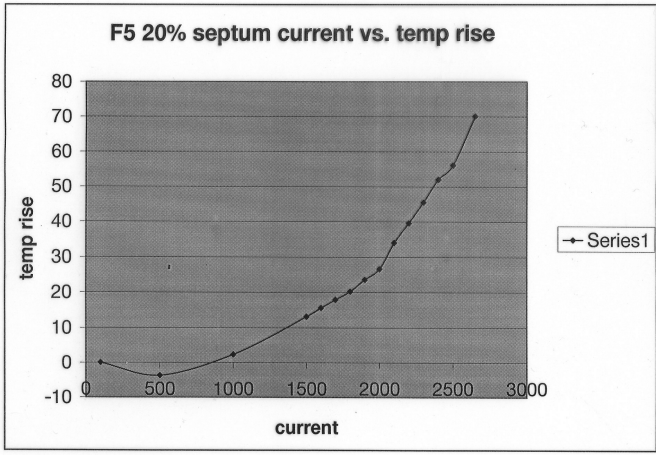
MATCHES TEST DATA

COMPARISON BETWEEN EXISTING AND 20% SEPTUM

	EXISTING F5		20% SEPTUM	
GAP	0.678"		0.823"	
THICKNESS	0.032"		0.026"	
C.S. AREA	0.02676 in^2		0.02623in^2	
WATER FLOW	1.8 GPM		1.8 GPM	
CURRENT	WATER T_R	SEPTUM T_R	WATER T_R	SEPTUM T_R
2000	16C	65C	25C	26.6C
2200	21C	79C	32C	39.5C
2650			51C	70C



.67" GAP X .032" THICK SEPTUM TESTED DC 1.8 GPM WATER FLOW



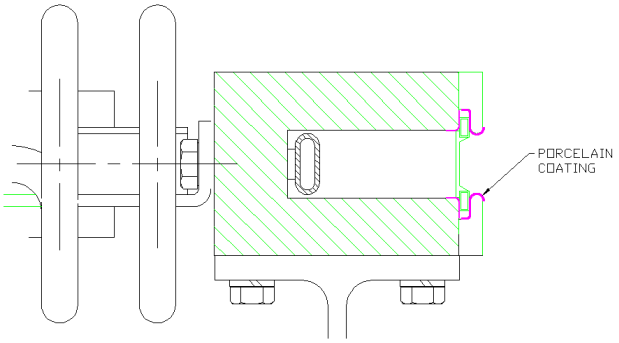
.823" GAP X .026" THICK SEPTUM TESTED DC WITH 1.8 GPM WATER FLOW

BROOKHAVEN NATIONAL LABORATORY

PORCELAIN COATING

PHYSICAL PROPERTIES OF PORCELAIN ENAMEL

Compressive Strength	138MPa
Rockwell Hardness C	90
Modulus of Elasticity	6900 Mpa
Dielectric Strength	~20 kV/mm
Outgassing Rates	
Before bake	5.5e-11mbar l/s cm
After 200°C bake	6e-13
Bled to N_2 after bake	1.7e-11
Radiation Hard	
High Temperature Resistance	



PORCELAIN COATED MAGNET CORE

APPLICATION OF PORCELAIN

- PARTS BEAD BLASTED IN AREAS TO BE COATED
- PORCELAIN PREMILL MIXED WITH WATER AND APPLIED WITH PNEUMATIC SPRAYER
- PARTS ARE DRIED IN AIR OVEN AT 100°C FOR 15 MINUTES
- PART ARE FIRED IN AIR FURNACE AT 850°C UNTIL ENAMEL MELTS AND WETS PART

PORCELAIN COATED PARTS

PHOTO RIPP BOWMAN
FILE# 4-0013-03

BROOKHAVEN NATIONAL LABORATORY

D3 Booster Thin Septum

D3 Septum parameters

Current – 1500 A nominal

Field – 0.6 Kg

Septum Thickness 0.76 mm (.029")

Gap – 25.4 mm (1")

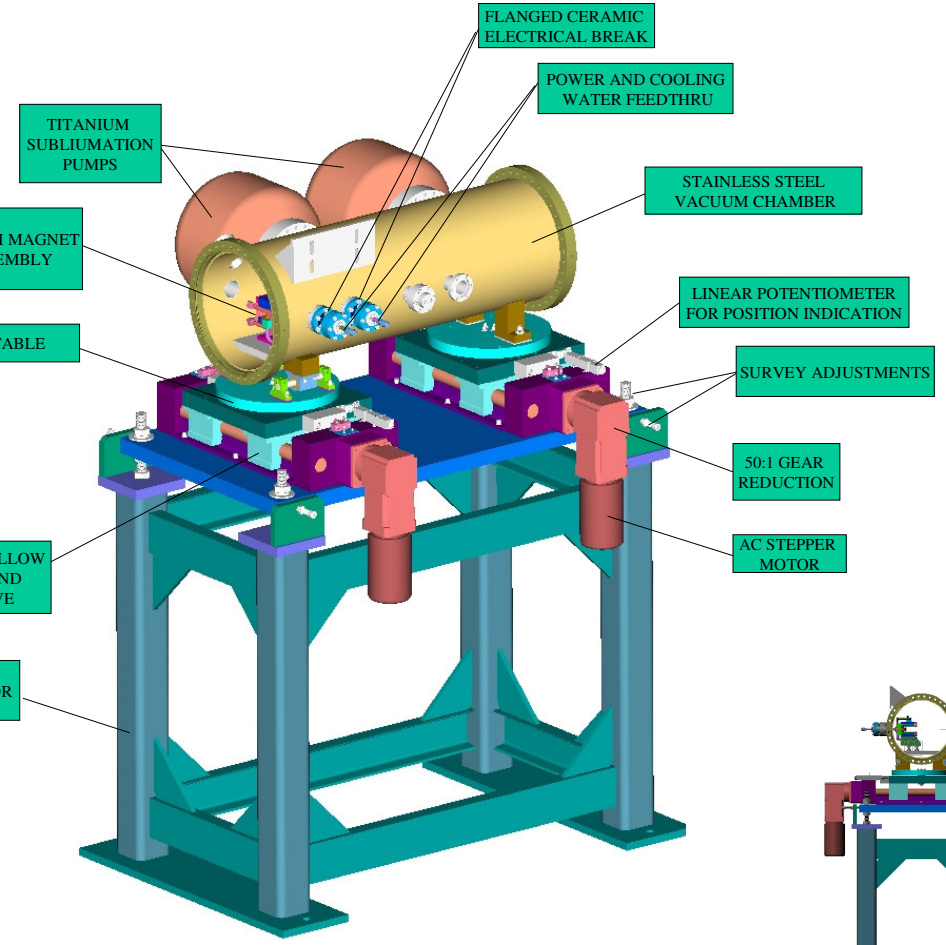
Length – 838.2 mm (33")

Core- solid 1006 steel

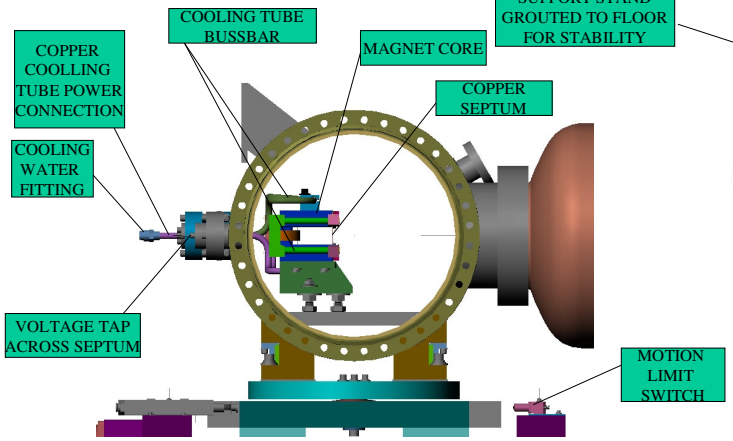
Cooling water Flow- 4gpm @100psi drop

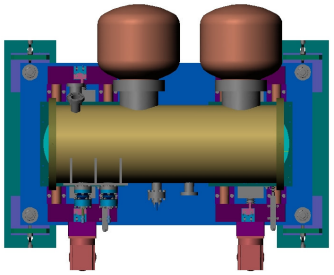
Vacuum 1x10^{-11} Torr

Bakeable – 300^{o}C

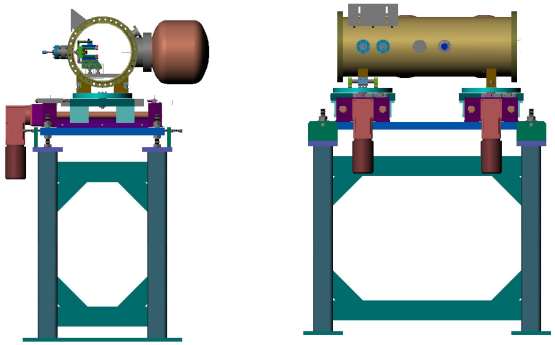


ISOMETRIC VIEW OF MAGNET MOUNTED ON DRIVE SYSTEM AND SUPPORT STAND





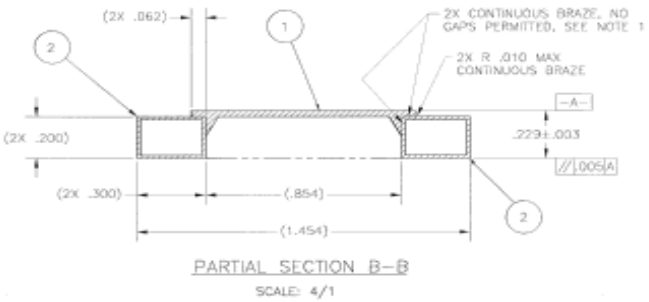
PLAN VIEW OF SEPTUM MAGNET ASSEMBLY



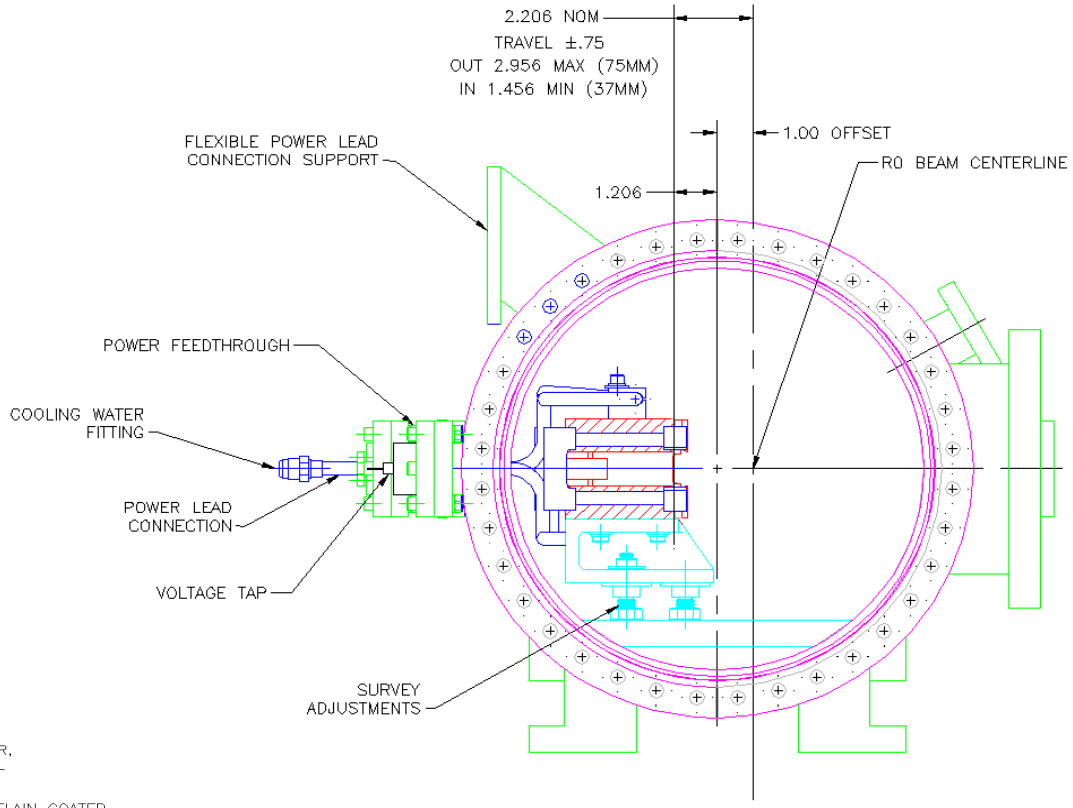
ELEVATION VIEWS OF SEPTUM MAGNET ASSEMBLY

BROOKHAVEN NATIONAL LABORATORY

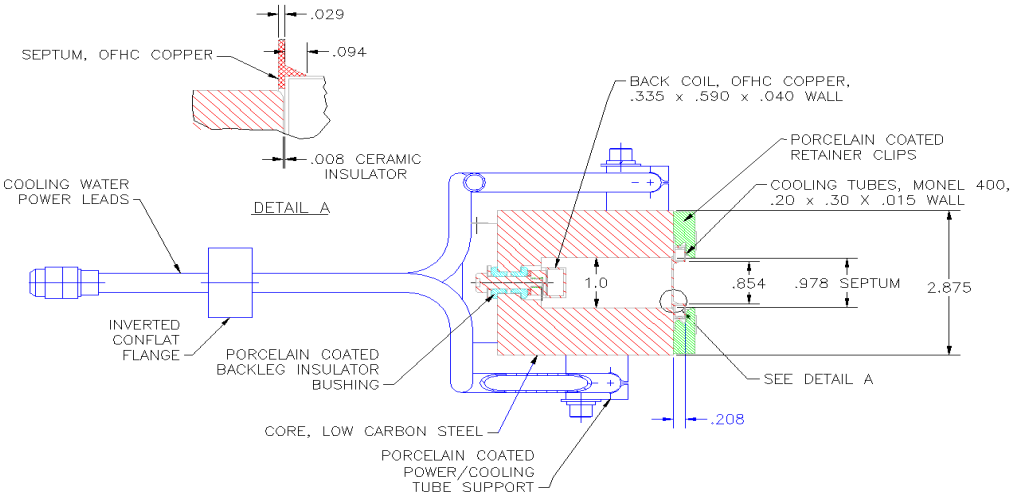
D3 SEPTUM DETAILS



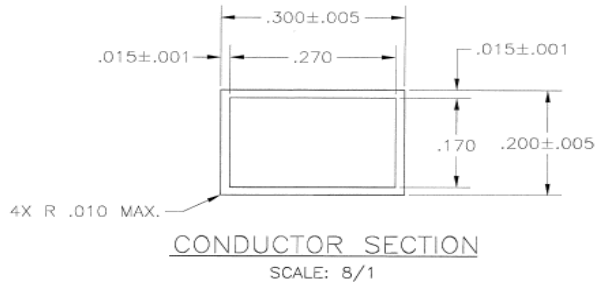
SEPTUM CROSS SECTION



MAGNET ASSY END VIEW



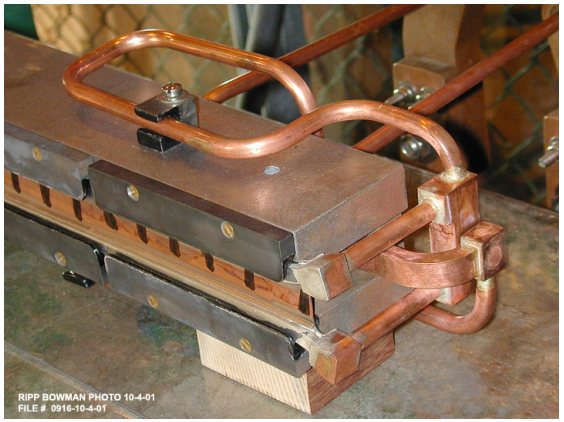
CORE ASSY CROSS SECTION

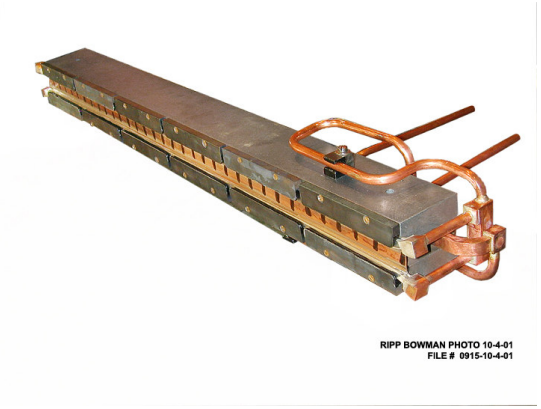


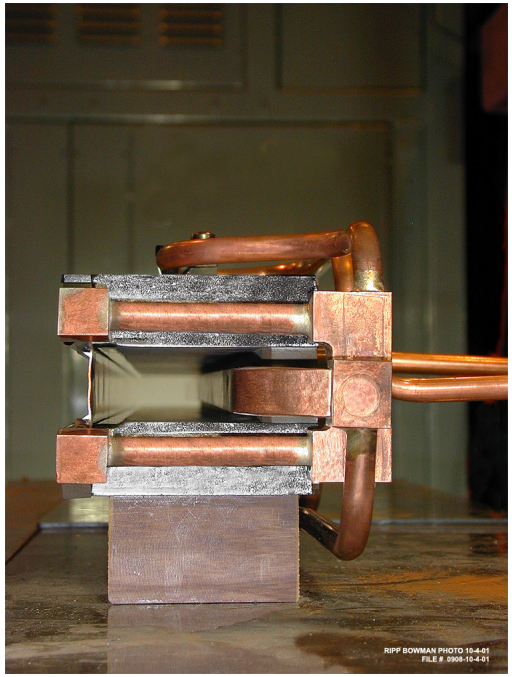
COOLING TUBE CROSS SECTION

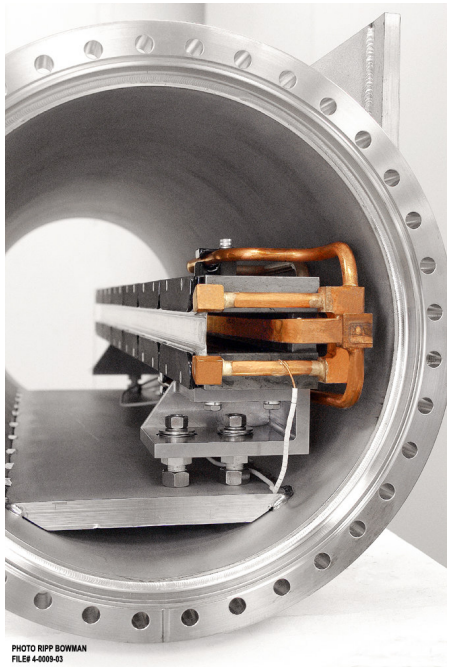
BROOKHAVEN NATIONAL LABORATORY

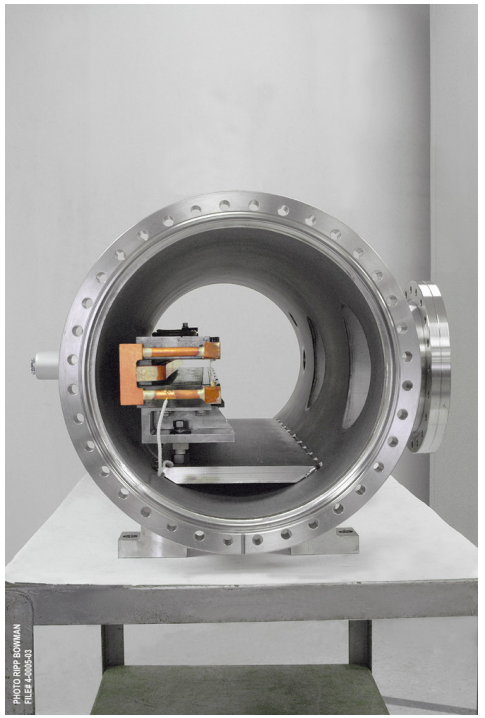
D3 SEPTUM ASSEMBLY





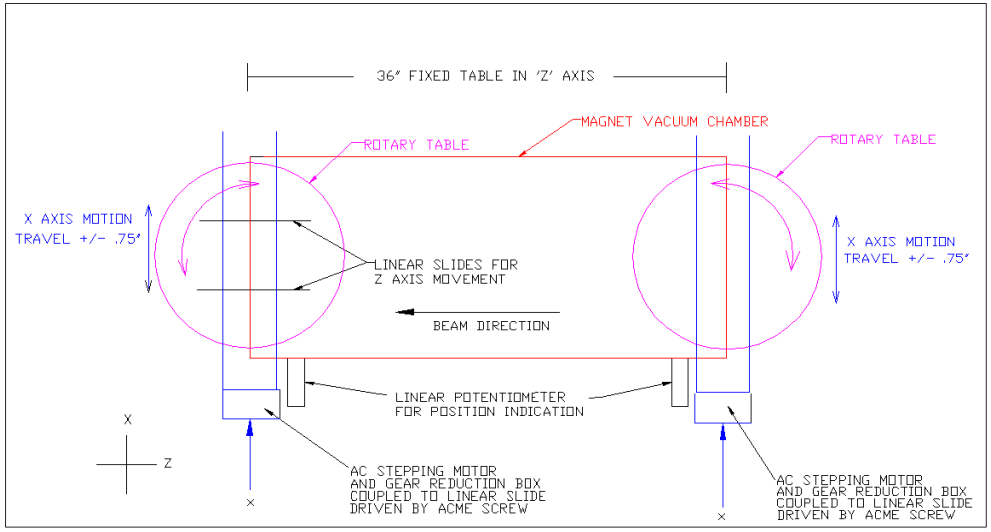


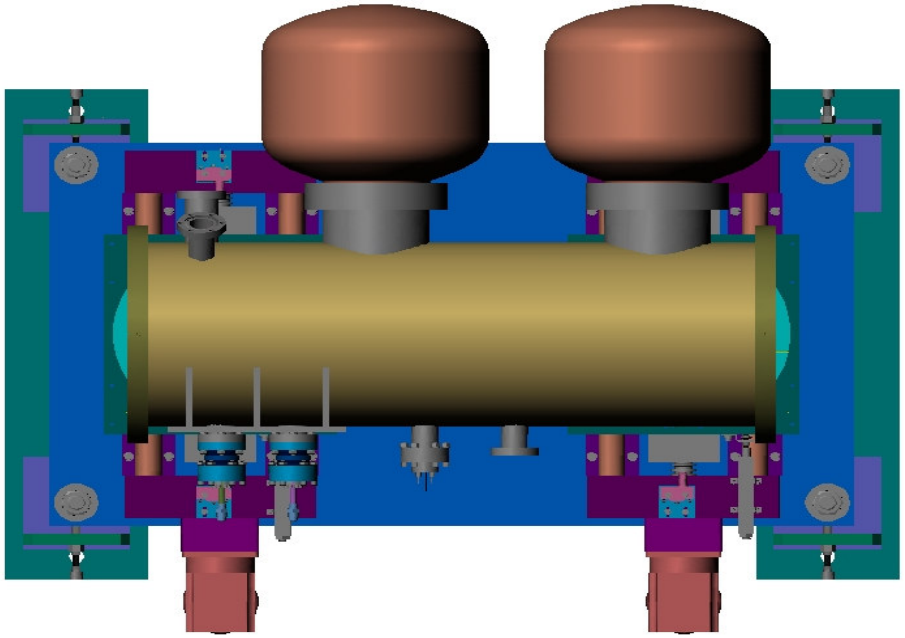




BROOKHAVEN NATIONAL LABORATORY

D3 SEPTUM MOTION SYSTEM

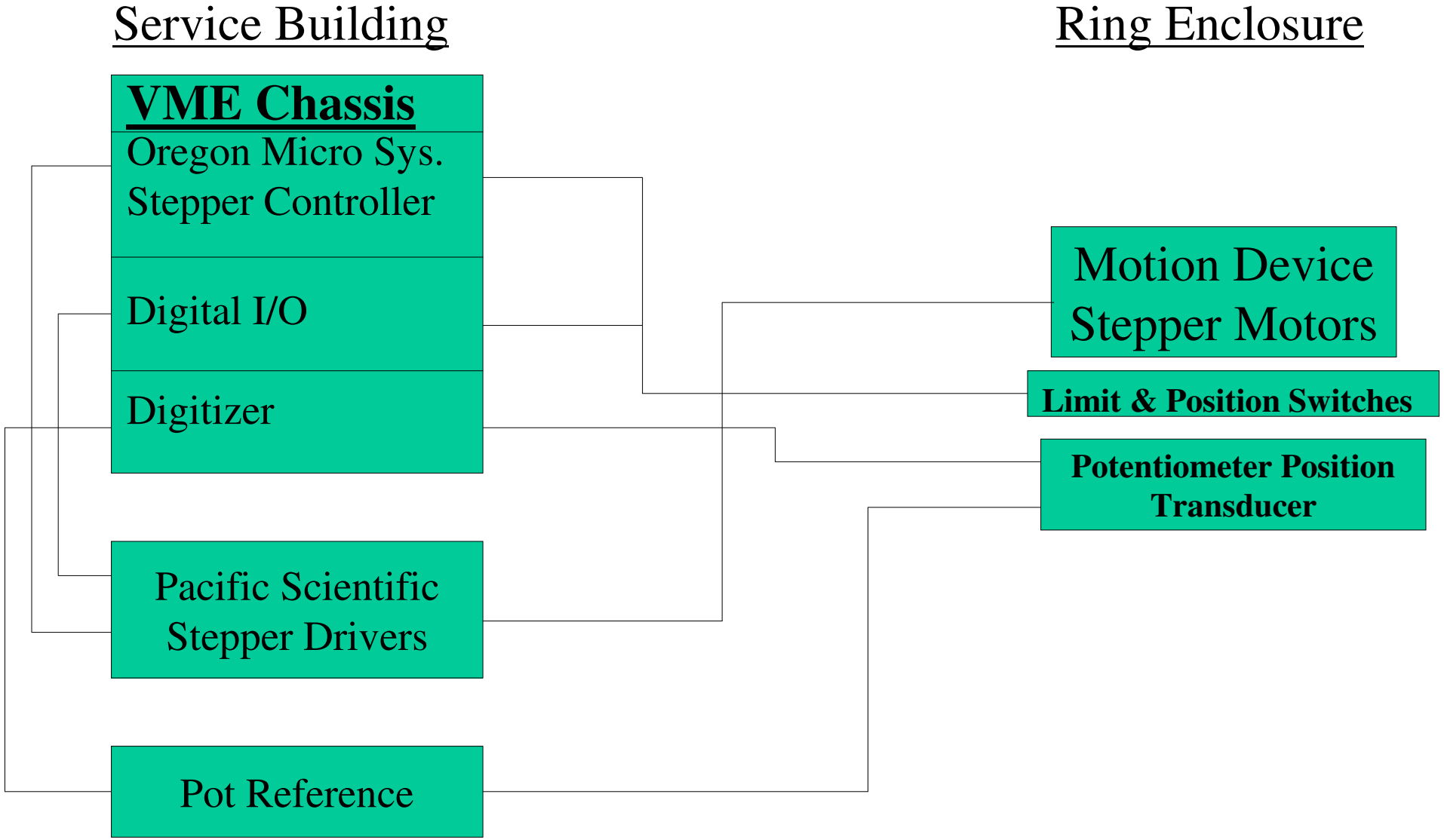




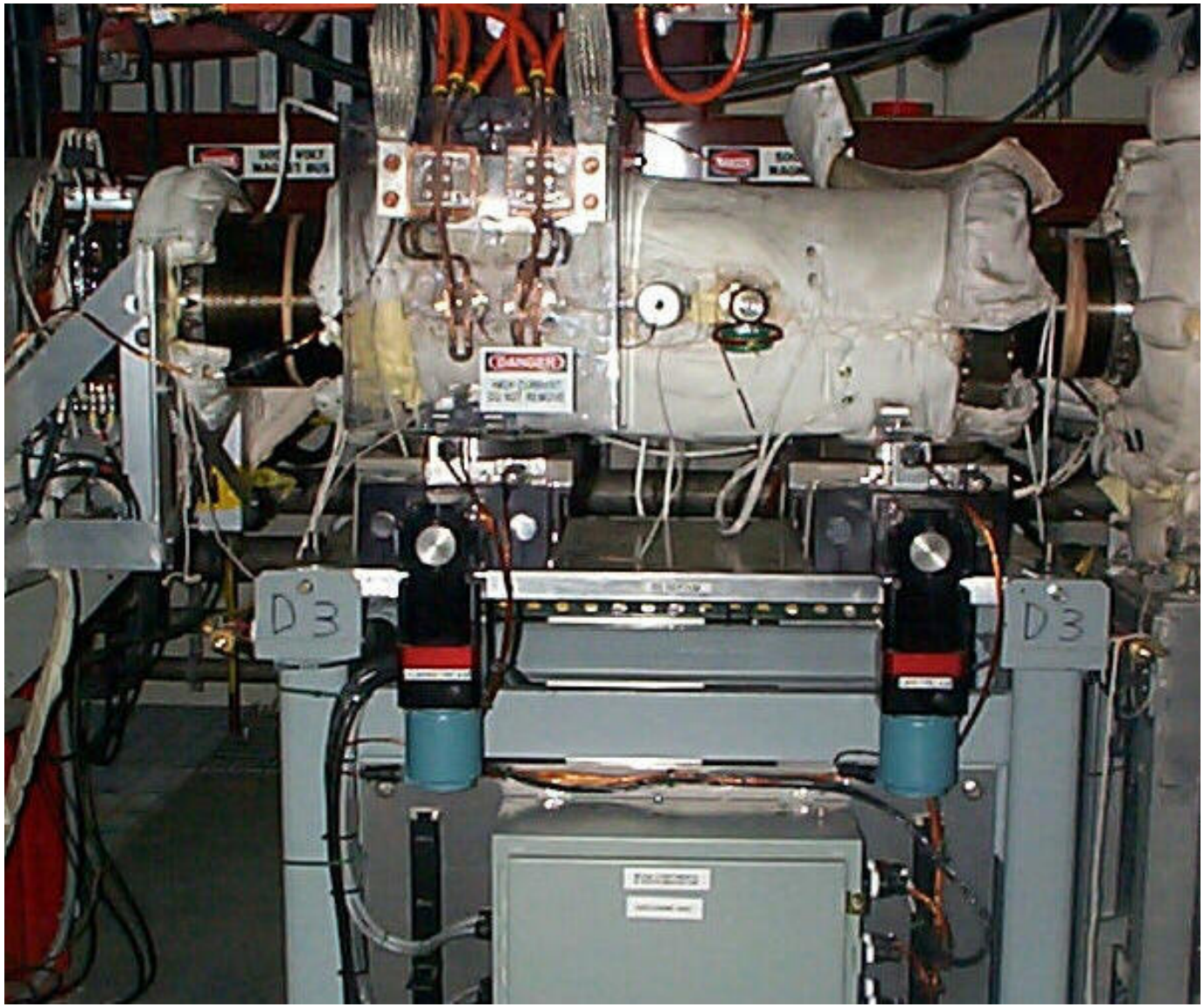
- Commercial linear slides
- Rotary tables on slides
- Acme screw drives
- 50:1 gear reduction
- AC stepper motors
- Linear potentiometers
- Limit switches

BROOKHAVEN NATIONAL LABORATORY

D3 Stepper Motion Control



D3 SEPTUM INSTALLATION IN BOOSTER RING



BROOKHAVEN
NATIONAL LABORATORY

BROOKHAVEN NATIONAL LABORATORY

FUTURE & EXISTING SEPTUM DATA

	EXISTING F5	FUTURE F5	D3
VERTICAL GAP	17.78mm(.67”)	22.9 mm (0.9”)	25.4 mm (1”)
LENGTH	0.667m (26.2”)	0.667m (26.2”)	838.2 mm (33”)
HORIZONTAL GAP	44.4mm (1.75”)	44.4mm (1.75”)	45.72mm (1.8”)
SEPTUM THICKNESS	0.81mm (.032”)	0.76 mm (.029”)	0.76 mm (.029”)
CURRENT	2100 A	2730 A	1500 A
FIELD	1.5 kG	2.0 kG	0.6 kg
BEND ANGLE	1.1mrad	1.1mrad	3 mrad

CONCLUSION

•PURSUE SEPTUM COOLING IMPROVEMENTS TO ALLOW RUNNING AT HIGHER CURRENTS

•EXPLORE THE USE OF ADDITIONAL COIL ON BACKSIDE OF MAGNET TO REDUCE FRINGE FIELD IN CIRCULATING BEAM AREA